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LOCAL
Engineering Data

FOR

ST. LOUIS.

COMPILED BY

THE ENGINEERS' CLUB

OF

ST. LOUIS.



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Publisher
OCT 27 1915



L. E. T. May 9/22

INTRODUCTORY NOTE.

THIS book is the outgrowth of a belief on the part of the Engineers' Club of St. Louis that a record of such engineering data as are peculiar to this city would be of permanent value to its members.

It is divided into two sections, Local Conditions and Local Materials. The first gives the general facts of the geodetic position, climate and geological formations of St. Louis, and the cost of works affected thereby. The second treats of such materials as are found here, or are largely used in local engineering works.

The committee desire to express their obligations to the members of the Club who have assisted them, and without whose help their work could not have been accomplished.

St. Louis, 1893.

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PART I.

LOCAL CONDITIONS.

GEODETIC AND ASTRONOMICAL DATA FOR ST. LOUIS.

The Washington University Observatory, which stands on the corner of Eighteenth and St. Charles streets, St. Louis, has a longitude 6h., 0m., 49.16s. from Greenwich and 0h., 52m., 37.07s. from Washington. Our local time is therefore 49.16 seconds slow of standard central time.

This point has a geodetic latitude of $38^{\circ} 38' 3.6''$ and a geocentric latitude of $38^{\circ} 26' 50.4''$.

From the geocentric latitude and elevation above sea level, may be computed the radius vector of the earth at St. Louis, the logarithm of which is 9.999437.

One degree of latitude at St. Louis is equal to 68.970 statute miles, while a degree of longitude is equal to 54.097 statute miles. In this latitude the sun crosses the meridian at an altitude varying from $27^{\circ} 56'.5$ at the winter solstice, to $74^{\circ} 49'.2$ at the summer solstice. The longest day at St. Louis is 14 hours, 52 minutes and

16 seconds; the shortest is 9 hours, 27 minutes and 44 seconds. On the longest day the sun sets $31^{\circ} 24.7$ north of west; on the shortest day it sets $29^{\circ} 51'.2$ south of west.*

MAGNETIC DECLINATION.

In connection with the latitude and longitude, the magnetic declination is of interest. In the year 1890 the eastern declination was diminishing at the rate of $4.4'$ per annum. The following table shows the magnetic declination since 1800:

Year.....	1810	1820	1830	1840	1850	1860	1870	1880	1890
† Declination	$-8^{\circ} 47'$	$-8^{\circ} 55'$	$-8^{\circ} 52'$	$-8^{\circ} 38'$	$-8^{\circ} 14'$	$-7^{\circ} 43'$	$-7^{\circ} 6'$	$-6^{\circ} 23'$	$-5^{\circ} 39'$

CITY DIRECTRIX AND TOPOGRAPHY.

The city directrix, which is below the high-water mark of the river, and which is taken as the datum for city topography is 412.71 feet above mean tide water of the Gulf of Mexico at Biloxi. The banks of Compton Hill reservoir, which commands the improved parts of the city, are 180 feet above this datum. The highest ground within the city limits is about 200 feet above the city directrix.

* The above data were obtained from H. S. Pritchett, Professor of Astronomy at Washington University. The lengths of longest and shortest days, and the azimuths of sun were computed rigorously, using corrections for refraction and parallax.

† See U. S. C. & G. Survey Report.

CLIMATE.

TEMPERATURE.

The following table* is a summary of temperature observations from 1871 to 1889 inclusive, tabulated by months:

Highest Mean Temperature Observed and Year of Occurrence.

Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov	Dec	Annual.
45.7	43.9	50.9	61.3	71.4	79.7	83.7	82.5	75.3	62.8	49.6	49.8	57.5
1880	1882	1871	1878	1887	1871	1887	1881	1881	1884	1883	1889	1871 & 1887

Lowest Mean Temperature Observed and Year of Occurrence.

Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov	Dec	Annual.
21.7	26.0	37.8	47.6	59.5	70.6	73.8	72.8	64.9	52.0	31.9	24.9	53.6
1881	1875	1872	1874	1882	1889	1882	1883	1879	1873	1880	1876	1883

Average Mean Temperature Deduced from 19 Years' Observations.

Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov	Dec	Annual.
30.3	31.2	43.3	56.0	66.2	74.4	79.1	76.7	68.6	57.5	43.3	35.1	55.5

To compare with this we have from another authority† the following summary:

Maximum and Minimum Temperatures (1838 to 1881, inclusive), with the Year of Occurrence.

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep	Oct	Nov.	Dec.
72 1843	81 1840	86 1842	93 1838, 55	97 1870, 71	102 1870	104+ 1860	102+ 1850, 61	102+ 1864	91+ 1867	80+ 1850	74 1861, 75
-23 1873	-15+ 1856	0+ 1848	18+ 1857	29+ 1851	43 1838, 9	53+ 1859	45+ 1863	35 1838	21+ 1863	0 1839, 45	-20 1872

Mean Monthly Temperature for the same period.

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
31.8	35.3	44.0	56.2	66.4	74.7	77.2	77.1	69.1	56.0	42.7	33.3

Annual mean, 55.3.

All temperatures are in degrees Fahrenheit.

*Furnished by A. W. Greely, Chief Signal Officer, U. S. A.

†Dr. Geo. Englemann.

‡Exposed thermometer.

The length of the winters gives a good index to climate. The period of danger from frost in St. Louis has been observed as follows:

Earliest first killing frost, October 3d, 1885.

Latest first killing frost, November 20th, 1879.

Earliest last killing frost, February 27th, 1878.

Latest last killing frost, May 2d, 1875.

Average date of first killing frost, October 31st.

Average date of last killing frost, March 30th.

Another good index of the severity of a climate may be found in the amount of artificial heat needed in city buildings.*

COAL CONSUMED IN HEATING BUILDINGS BY STEAM.

With a view to finding a safe unit upon which to estimate the amount of coal required to heat a given building, the following figures are given for three of the principal buildings in the city of St. Louis. All of these buildings are well known and recognized as being first-class in design, construction and appointments. The amount of heat required for any building depends greatly upon three factors:

First.—The cubic contents or space to be warmed.

Second.—The areas of the exposed surfaces in walls, doors and windows through which the heat escapes.

Third.—The time during which heat is to be kept up.

The comparative results given below apply directly to buildings of similar good design and construction.

The dimensions are taken from the architect's plans, and the amount of coal consumed per month from reports made by the agents. The running time of engines and pumps has been obtained from records kept by the

*See Note 1.

engineers. The average of the results shown would represent good local practice with Illinois coal.

Building A. Outside dimensions 123' x 68' x 100', eight stories high. The south side is sheltered for seven stories by adjoining buildings, making all the exposures most severe. The north front has further a large recess, making actual length of exposure much greater than the length of the building; it also stands on high ground and is exposed to all the severe winds.

Building B. The outside dimensions 97' x 68' x 90', eight stories high. The north side is sheltered for seven stories by adjoining buildings, making all the exposure most favorable, excepting the east fronts. It stands on lower ground than A, and is better sheltered by the neighboring buildings.

Building C. Outside dimensions 180' x 225' x 88', six stories high. Exposed all around, but west front sheltered by neighboring buildings. It stands upon about the same elevation as building B, and is equally well sheltered by neighboring buildings.

Building.	Cubical Contents.	* EXPOSED AREA.					Lbs. Coal per hour for Heating.	Lbs. Coal per hour per 1000 cubic ft. Contents.	Lbs. Coal per hour per 1000 Sqr. ft. Exposure.
		North.	South.	East.	West.	Total.			
A..	750,000	20,000	3,500	6,700	6,700	36,900	233.0	0.310	6.30
B..	650,000	.....	9,800	9,700	9,700	29,200	275.0	0.423	9.49
C..	3,228,000	14,700	14,700	35,300	35,300	100,000	1024.0	0.317	10.24

* Roof exposure is not counted.

We may learn something of a climate by a study of the records of barometric readings and wind directions and velocities, such as is shown in the following table:

ATMOSPHERIC PRESSURES AND VELOCITIES.

Highest Barometric Readings (1880 to 1889, inclusive,) Reduced to Sea Level.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
30.94	30.90	30.67	30.52	30.37	30.34	30.36	30.30	30.47	30.54	30.80	30.94

Lowest Barometric Readings (1880 to 1889, inclusive,) Reduced to Sea Level.

29.31	29.20	29.15	29.36	29.48	29.54	29.69	29.67	29.59	29.49	29.51	29.32
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

Mean Monthly Pressure Deduced from 15 Years Observations.

30.16	30.13	30.06	29.97	29.96	29.96	29.99	29.99	30.05	30.08	30.12	30.15
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

Prevailing Wind Direction Deduced from 19 Years Observations.

N-W.	N-W.	N-W.	S.	S.	S.	S.	S.	S.	S.	S.	S.
------	------	------	----	----	----	----	----	----	----	----	----

Maximum Velocity of Wind, Miles per Hour (1873 to 1889, inclusive,) and Year of Occurrence.

42	39	41	44	48	49	39	57	39	44	44	48
1888	1876 1888 1889	1873	1875	1878	1882	1877	1878	1878 1885	1887	1887	1885

RAINFALL.*

Monthly rainfalls of over 10 inches have been observed twice in May, five times in June, once each in July, September, November and December.

The most violent St. Louis rain on record, occurred August 15, 1848, when 5.05 inches fell in seventy-five minutes. During that same year, between May 6 and

* See note 2.

August 15, there were five rains which gave an aggregate rainfall of 24 inches, the actual duration of rainfall being thirty-eight hours.

The monthly rainfall has been less than half an inch fifteen times since 1838.

In 1849, during August and September, the rainfall was only 0.75 inch. The three months preceding, however, gave a rainfall of 26 inches.

At Oregon, Holt Co., Mo., rainfall observations, by Wm. Kaucher, show that the annual rainfall has varied from 27 to 49 inches since 1855. The average was 35.97 inches.

The highest monthly rainfall there was 14.91 inches, in June, 1883. The rainfall has been over 10 inches once each in May, June, July, since 1855; six times the monthly rainfall has been less than 0.25 inch, the least, 0.03, occurring February, 1870.

PRECIPITATION AT ST. LOUIS.

SUMMARY OF TABLE FROM OBSERVATIONS FURNISHED BY DR. GEO. ENGLEMAN
1838 TO 1881, INCLUSIVE.

*Maximum and Minimum Monthly and Annual Precipitation, in Inches, with the
Year of Occurrence.*

Jan.	Feb.	Mar.	April	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
4.66 1855	7.74 1857	8.61 1865	7.68 1850	11.26 1844	17.07 1848	10.00 1875	9.74 1848	10.53 1866	8.74 1847	8.63 1847	10.90 1846	68.83 1858
0.39 1881	0.55 1868	0.79 1853	0.25 1871	0.96 1879	0.41 1864	0.84 1846	0.04 1873	0.02 1871	0.29 1872	0.00 1865	0.19 1876	21.87 1871

Mean Monthly and Annual Precipitation, in Inches.

2.19	2.54	3.60	3.72	4.60	5.22	4.14	4.07	2.90	2.96	2.89	2.86	41.69
------	------	------	------	------	------	------	------	------	------	------	------	-------

In connection with the rainfall, the amount of water which will reach sewers and drains is of interest to engineers.

STORM-WATER FLOW IN SEWERS. *

St. Louis sewers, from the beginning, are said to have been proportioned to carry off one inch of rainfall per hour; what portion of the sewer section was supposed to be filled by that flow, during the earlier years of sewer construction, is not known. Mr. Robert Moore, who became sewer commissioner in 1877, adopted the formula $D = \left[\frac{N^2}{10 H} \right]^{\frac{1}{5}}$. D being the diameter of circular sewer, H the fall in feet per 100, and N the number of acres drained; the sewer being supposed to run three-fourths full. Possibly in earlier years the common supposition of half full was used. Mr. Moore made tables to guide in proportioning sewers, which were published in the first volume of the *Journal of the Association of Engineering Societies*. These tables are still used in proportioning the smaller sewers, and the results, so far as known, have proven satisfactory.

It is well known that rainfalls, much in excess of 1 inch per hour, frequently occur in St. Louis. That the sewers are not overtaxed is due to several causes. Among them, first: The real capacity of the sewers is considerably in excess of that assumed; the ratio of assumed to real capacity ranging, for pipe sewers, from 79 per cent. for 12-inch pipe, to 67 per cent. for 24-inch pipe, and, for brick sewers, from 75 per cent. for 2 feet 6 in. diameter, to 57 per cent. for a sewer 12 feet in diameter. Second: Most of the smaller sewers can run under a head without flooding the adjoining property so as to call attention to the fact of being overcharged. Running under unknown head, the discharge may be

* See note 3.

greatly in excess of that computed, as due to the grade. Third: Many of the areas drained have not been fully improved, consequently the proportion of rainfall reaching the sewers during the storm has not reached a maximum.

From a study of St. Louis sewers that are known to be overtaxed, and taking into account their capacity, computed by Kutter's formula, the quantity of water reaching the sewers may be fairly represented by the formula $Q = 2.0625 \sqrt[5]{S A^4}$, in which A is area in acres, and S the mean surface grade in feet, per thousand. This result, which differs from the well-known Burkli-Zeigler formula, in using the fifth instead of the fourth root, agrees quite well with the results of sewer gaugings made in New York city by Rudolph Hering, C. E.

GEOLOGICAL FORMATIONS.*

Geologically speaking, St. Louis rests on lower coal measure and upper sub-carboniferous rocks. Our coal measure rocks contain a workable seam of bituminous coal, which was found at a depth of 60 or 80 feet or less. Valuable beds of fire-clay also are contained in these strata. The sub-carboniferous rocks belong to the St. Louis group of limestones. This group shows a depth of 200 to 250 feet at Alton, Ill. This limestone is sometimes massive and sometimes in thin beds. It has a decided cavernous character, as is shown by the numerous sink-holes in parts of the city. The stone is valuable for making lime and is largely used for street and building purposes.

* See Note 4.

From a deep well at the Insane Asylum the following section was obtained:

- 40 feet. . Clays.
- 80 " .. Coal measure rocks.
- 670 " .. Lower carboniferous rocks.
- 93 " .. Chouteau limestone.
- 421 " .. Trenton, Black River and Birdseye limestone.
- 148 " .. 1st magnesian limestone.
- 133 " .. Saccharoidal "
- 517 " .. 2d magnesian "
- 82 " .. 2d sandstone.
- 83 " .. 3d magnesian limestone.
- 98 " .. 3d sandstone.
- 384 " .. 4th magnesian limestone.
- 54 " .. Potsdam sandstone.
- 245 " .. Granite and sandstone.
- 40 " .. Granite.

The total depth bored was 3,843.5 feet, and the surface is here 583 feet above the level of the Gulf of Mexico. At the bottom of the well a registering thermometer showed a temperature of 105° F.

At Jefferson Barracks, south of St. Louis, the Warsaw limestone is found, which is the base of the St. Louis group; at Cliff Cave we have the Keokuk limestone and at Kimmswick the Burlington limestone, all sub-carboniferous. At Pevely we drop to lower silurian and at Crystal City we find the saccharoidal or St. Peter's sandstone, a very soft, pure and white sandstone, which is here 40 or 50 feet thick and is used for glass-making.

Going west from the city, we find at Kirkwood, St. Louis limestone, and at Glencoe, Trenton limestone, lower

silurian. Three miles to the north of Glencoe, deposits of drift are found consisting of rounded siliceous pebbles.

Going towards St. Charles, we pass over middle coal measures and find at St. Charles, the St. Louis limestone. Going up the river, we find at the Chain of Rocks St. Louis limestone covered by coal measures. At Alton we have the same. At Jersey Landing the entire Illinois bluff, about 200 feet high, is composed of Burlington limestone, which also caps the bluffs at Grafton. At Grafton, we find Niagara limestone, upper silurian, which here forms a cliff of bluff dolomite, rising 80 to 90 feet above low water. These ledges are extensively quarried for building stone.

In the Illinois bluffs opposite our city we have the outcrop of the Belleville coal seam, which consists of from 5 to 7 feet of valuable bituminous coal.

COST OF ROCK EXCAVATION.

The cost of rock excavation in open cut is usually estimated at about \$2.00 per cubic yard, more or less, according to conditions.

The inlet tunnel for the waterworks, which was driven through solid limestone, with a section 10x10 to 10x16 feet, cost about \$6.00 per cubic yard of excavation, or \$23.46 per lineal foot.

Sinking shaft for inlet tower on same work, shaft circular and 10 feet in diameter, cost as follows:

Drilling done by hand, little pumping required, cost per foot of depth:

Labor account.....	\$34.50
Dynamite (5.6 lbs. at 25 cents).....	1.40
	\$35.90

CLAYS AND COST OF EXCAVATION.*

The rocks beneath our city are concealed under a covering of earth. On the hills we have usually a yellow bluff clay, which gives an excellent foundation for buildings. It is readily excavated and usually stands well without bracing. The best of it makes very good clay puddle and is used extensively for the manufacture of red brick.

In the bottom lands we find a tenacious blue clay or "gumbo" and beds of sand, which, when saturated with water, are excavated with difficulty.

Earth excavation above the water-line, with a short haul, is usually estimated at about 15 cents per cubic yard.

In excavating for the waterworks conduit, a New Era Excavator was used, with six teams and drivers, three laborers and one head plowman, at an average total cost of operation of \$30.75 per day, and removed about 600 cubic yards per day at a cost of $5\frac{1}{8}$ cents per yard.

COST OF LAYING WATER PIPE.

The cost of laying water pipes of all sizes as it is done by the city, may be roughly estimated at from \$8.00 to \$10.00 per ton of 2000 pounds.

COST OF PUTTING IN DEEP FOUNDATIONS FOR THE ST. LOUIS AQUEDUCT.**Sheet Piling.****COST OF DRIVING PILES IN PIER NO. 4, MALINE CREEK BRIDGE.**

Two rows of piling were used. The top row, 14 feet long, was driven around a frame 15' x 28'.5. The earth was excavated and the second row, 16 feet long, was

* See note 5.

driven to rock inside of the first row, around a frame 9' x 22'.5. Weight of hammer about 1,500 lbs. The material was clay inside of the top row of piling, and layers of clay and quicksand in the second row.

Cost of Working Driver.

1 superintendent	@ \$3.33.....	\$ 3.33
1 master of pile driver	@ 3.00.....	3.00
1 engineer	@ 2.50.....	2.50
5 laborers	@ 1.75.....	8.75
1 engine, etc.,	@ 2.00.....	2.00
Coal, 20 bu.,	@ .09.....	1.80

Total for 10 hours.....\$21.38

or \$2.138 per hour.

Top Row of Piling—85 piles, 6" x 10" x 14, =1190 lineal feet.

Placing frame and machin-		Per lin. foot.
ery, 5 hours	@ \$2.138..	\$10.69, or 0.009
Driving piles, 15 "	@ 2.138..	32.07, or 0.0269
Clearing pit, 1 "	@ 2.138..	2.138, or 0.0018
Totals . . . 21	@ \$2.138..	\$44.898, or 0.0377

Bottom row of piling, 60 piles 6" x 12" x 16' =960 lin. ft.

The hammer line passed through two snatch-blocks before going to engine.

Putting in frame and driver,
changing engine, etc.,

		Per lin. foot.
4 hours,	@ \$2.138..	\$ 8.55, or \$0.0089
Driving piles, 20 "	@ 2.138..	42.76, or 0.0445
Total . . . 24 "	\$2.138..	<u>\$51.31</u> , or <u>\$0.0534</u>

Excavation.

Cost of Earth Excavation inside of top sheet piling of
Pier No. 4, Maline Creek Bridge.

The material was wet blue clay and handled well.

Foreman,	3	days,	@	\$3.33.....	\$10.00
“	2½	“	@	3.00.....	7.50
Engineer,	2½	“	@	2.50.....	6.25
Laborers,	22	“	@	1.75.....	38.50
Teams,	3½	“	@	3.50.....	12.25
Engine, etc.	2½	“	@	2.00.....	5.00
Coal, 35 bu.			@	.09.....	3.15
Total.					<u>\$82.65</u>

Size of pit, 15' x 28'.5 x 12' deep.

Cubic yards, 190.

Cost per cubic yard, \$0.435.

Cost of Earth Excavation inside of the bottom row of
sheet piling, Pier No. 4, Maline Creek Bridge.

The material was blue clay and quicksand, carrying a large amount of water. The bottom of the sheet piling was about 25 feet below the elevation of the ground water. The pumping and bracing required about one-half of the total amount of labor.

Foreman,	8	days,	@	\$3.33.....	\$ 26 67
“	12.3	“	@	3.00.....	36.90
Engineer,	6.1	“	@	2.50.....	15.25
Laborers,	68.9	“	@	1.75.....	120.575
Engine, etc.	6.1	“	@	2.00.....	12.20
Teams,	9.6	“	@	3.50.....	33.60
Coal, 90 bu.			@	.09.....	8.10
Total.					<u>\$253.295</u>

Size of pit, 9' x 22'.5 x 15' deep=112.5 cu. yds.

Cost per cubic yard of pit, \$2.252

Inside of top piling, 190 cu. yds...\$ 82.65

“ “ bottom “ 112.5 “ .. 253.295

302.5 \$335.945

Average cost per cu.yd.for the whole pit, \$1.112

Before making excavations in earth of a doubtful nature, it is often advisable to test the ground by boring. The following notes, on the labor and cost of boring, will thus be of interest to the engineer.

COST OF EARTH BORINGS.*

The instrument used was a 6-inch auger, and the material bored in was alluvial bottom at the Chain of Rocks. These borings were made as preliminary to the construction of the settling basins for the St. Louis Water Works Low Service Extension.

Average of 161 borings:

Average depth of borings.....16'.78

“ “ bored per day.....37'.00

“ cost of a boring.....\$2.95

“ “ per foot.....0.176

Eight hours was a day's work for the boring party, which consisted of one foreman, at \$2.50 per day, and two laborers, at \$2.00 each per day. The foreman was required to take samples of ground, on an average, about two feet apart. After a fine sand stratum was entered, the rate of boring was considerably reduced by the ground falling in. The average depth at which this stratum was entered was about nine feet.

*See note 6.

PRESSURE ON FOUNDATIONS.

The pressure or weight which earth will sustain, depends upon a number of conditions. The following examples, however, are given to convey a rough idea of local practice, which has proved successful :

The city water tower rests on bluff clay, at a depth of about twenty feet below the surface, with a uniform pressure on the foundation, estimated at 3,700 lbs. per square foot. *

The division walls of the old settling basins of the city water works rest on a filled foundation of clay, two feet thick, which rests in turn on alluvial ground, near the river bank. The natural conditions may be considered bad.

The pressure is sometimes on one side of the division wall and sometimes on the other. The maximum pressure under the toe of the wall is estimated at 3,200 lbs. per square foot. † This is at a depth of $3\frac{1}{2}$ feet below the floor of the basins. These walls have shown some settlement, but are still in good condition.

The data upon Local Conditions will be concluded with some notes on

THE MISSISSIPPI RIVER AT ST. LOUIS.‡**The St. Louis Gauge.**

The St. Louis gauge near the foot of Walnut street is the regular gauge on which continuous records of the stages of the river have been observed. All stages refer to the zero of this gauge as a datum.

This zero has the following connections :—33.74 feet below the St. Louis directrix ; 378.97 feet above mean Gulf tide [preliminary value] at Biloxi, by Mississippi

*See note 7.

†See note 6.

‡See note 8.

River Commission line of precise levels ; 382.62 feet above mean ocean tide at Sandy Hook, by U. S. Coast Survey line of precise levels.

High Waters.

High waters, prior to the regular record, have the following stages on this gauge :

For 1844=41.32 feet. For 1851=36.54 feet.

“ 1858=37.04 “ “ 1892=36.4 “

The following tables are self-explanatory :

Average and Extreme Monthly Stages (1861-88, inclusive).

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Max ...	17.5	28.2	25.7	31.5	33.6	34.8	32.2	29.8	22.2	25.1	29.5	20.6
Ave....	8.5	10.5	14.2	19.1	19.7	19.4	18.6	12.3	10.2	9.4	9.0	7.2
Min....	0.9	1.2	4.3	8.2	9.6	8.8	6.6	4.0	3.0	2.4	2.4	0.0

To show the rate of rise or fall of the river at flood, the following notes were made from the Water Works' records from April, 1872, to April, 1885. The gauge is three miles above the official gauge and reads from a datum 100 feet below the city directrix:

MAXIMUM RISE AND FALL OF RIVER AT HIGH STAGES.

Gauge.	Rise in 24 hours, feet.	Fall in 24 hours, feet.	Date.
92		4.2	August 8, 1875.
96	7.5		February 21, 1882.
98	3.5		August 2, 1875.
98		2.5	May 9, 1881.
99	3.2		May 8, 1876.
100		1.4	May 8, 1881.
101	2		May 9, 1876.
101		0.9	June 30, 1883.
102	0.9		June 20, 1883.
102		0.8	June 29, 1883.
103		0.5	June 27, 1883.
104	0.6		June 25, 1883.

DISCHARGE AND SEDIMENT OBSERVATIONS, RIVER AT ST. LOUIS, 1881.

Date, 1881.	Gauge.	Discharge Cubic feet per Sec.	Mean Ve- locity, feet per Sec.	Slope, feet per 1,000.	Sediment, parts in 100,000.
February 5... ..	7.55	47,128	2.42	.0842	19
" 25.....	10.90	127,652			
March 14.....	19.45	314,979			
" 16.....	20.10	348,910			
" 28... ..	20.90	363,188			
April 23.....	27.40	573,618	6.24	.1599	202
" 25.....	29.25	599,384	6.14	.1633	272
" 26.....	29.75	648,324	6.56		240
May 12.....	26.50	443,419	5.36		90
August 5.....	14.45	179,174		.0609	75
" 8.....	13.20	145,754	3.58	.0210	75
" 13.....	11.50	124,186	3.29	.0293	63
" 19.....	10.30	102,651	2.97		52
" 31.....	8.90	84,878	2.81		46
November 4.	24.40	552,834	7.62	.1440	

M. R. C. Report, 1882.

CLOSING OF NAVIGATION BY ICE.

The following notes on the closing of navigation on account of ice were compiled from various records, and cover the period from the fall of 1865 to the spring of 1889:

Date of earliest closing.....December 1st.

Date of latest closing.....February 14th.

Date of earliest opening.....December 12th.

Date of latest opening.....March 3d.

There were five winters during this period in which the river was not closed at all.

The highest stage reached while the river was closed was twenty-three feet on the gauge.

SEDIMENT IN RIVER WATER.

The following tables give the amount of sediment in the water from observations at St. Charles, Grafton and St. Louis:

Missouri River water at St. Charles, Mo.												
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Max.....		0.848	1.593	8.090	4.869	7.822	8.189	3.234	1.600	0.797		
Aver.....		0.523	0.849	4.332	3.197	5.114	5.463	2.617	1.163	0.672		
Min.....		0.292	0.368	0.767	2.276	3.359	2.720	1.678	0.668	0.577		

Rep. Mo. R. C., 1887.

Mississippi River water at Grafton, Ills.												
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Max.	0.050	0.410	0.750	0.470	0.440	0.890	1.080	0.230				
Aver.	0.033	0.169	0.494	0.263	0.174	0.455	0.402	0.119				
Min.	0.010	0.030	0.280	0.020	0.100	0.130	0.100	0.060				

Rep. M. R. C., 1882.

From Observations at the St. Louis Water Works.

1888.													
Settled Water.	Water Works Intake.												
	Max. Aver. Min.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Max.	0.517	1.209	1.092	0.760	0.817	0.384	0.963	0.774	0.218	0.186	0.194	0.208	0.208
Aver.	0.165	0.435	0.679	0.317	0.261	0.205	0.384	0.313	0.100	0.095	0.086	0.082	0.082
Min.	0.064	0.086	0.400	0.129	0.092	0.047	0.160	0.105	0.032	0.021	0.026	0.050	0.050

HARDNESS AND CHLORINE.

The table below shows the hardness and chlorine of the river water, from determinations made in the year 1886. In tests made during 1885, '86 and '87, the hardness ranged from 4.62 to 12.80. It is interesting to note that more chlorine is found on the Missouri side of the stream. The samples were all taken at the Chain of Rocks.

<i>Hardness in Degrees, Clark's Scale.</i>												
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mo. Side.	Max....	.....	8.06	7.42	7.89	9.77	7.29	7.89	8.06	8.97	8.61	12.32
	Ave....	.....	7.35	6.57	7.10	8.54	6.54	7.19	7.72	8.22	8.12	10.13
	Min....	.....	6.13	6.10	6.44	6.67	5.67	6.50	7.11	7.48	7.59	8.54
Ill. Side.	Max....	.....	8.60	7.48	7.89	9.90	7.86	8.70	8.91	8.68	7.43	.....
	Ave....	.....	7.72	6.89	6.58	8.59	7.22	8.18	7.95	7.40	6.79	.....
	Min....	.....	6.48	6.10	5.60	6.00	5.81	7.65	7.31	6.82	5.98	.....
<i>Chlorine, Grains per Gallon.</i>												
Mo. Side.	Max....	.....	0.84	0.62	0.54	0.92	0.70	1.46	1.11	1.22	1.28	2.51
	Ave....	.....	0.43	0.33	0.29	0.48	0.53	0.87	0.99	0.95	1.06	1.58
	Min....	.....	0.27	0.19	0.16	0.32	0.38	0.58	0.87	0.82	0.87	1.17
Ill. Side.	Max....	.....	0.30	0.27	0.27	0.49	0.52	0.58	0.55	0.47	0.50	.....
	Ave....	.....	0.24	0.20	0.17	0.33	0.38	0.50	0.44	0.39	0.38	.....
	Min....	.....	0.22	0.16	0.14	0.16	0.27	0.41	0.35	0.35	0.29	.....

PART II.

LOCAL MATERIALS.

STONE.

The following analyses* show the composition of limestone found in this vicinity. No. 10 was a sample of macadam taken from the city streets. No. 11 came from a quarry near Manchester, where building stone is obtained. No. 12 shows the range obtained from a number of analyses of stone used for making lime for the market.

	Loss by Ignition.	Silica.	Oxides of Iron and Aluminum	Lime.	Magnesia.
10 St. Louis Limestone (Macadam)...	43.51	0.41	0.28	54.53	0.24
11 " " County Limestone.....	42.49	3.32	0.56	53.35	0.25
12 Falling Springs (Ill.) Limestone...	41.13	0.66	0.34	51.87	0.00
	to	to	to	to	to
	43.56	6.14	0.87	55.19	2.06

To compare with the above we have an analysis† of a sample of the St. Louis limestone used in the gate house which rests on the inlet tower at the Chain of Rocks. The sample showed a coarse crystalline fracture.

* By Mr. Caldwell.

† By Mr. Jno. F. Wixford.

ST. LOUIS LIMESTONE.

	Per cent.
Silica and clay.....	= 0.781
Carbon dioxide $C O_2$	= 43.440
Alumina and ferric oxide, $Al_2 O_3 + Fe_2 O_3$	= 0.436
Lime, $Ca O$	= 55.323
Magnesia, $Mg O$	= 0.232
Total	100.212

Building stones from Grafton and Joliet, Ill., are largely used in our city. These stones are magnesian in character and belong to the geological formation known as the Niagara limestone upper silurian. In some tests made for the Eads' bridge, cubes of Grafton stone were found to have a crushing strength of 12,300 pounds per square inch, while granite stood from 11,700 to 16,400 pounds per square inch. The modulus of elasticity of the Grafton stone was found to be 8,600,000, while that of Maine granite was from 5,000,000 to 13,000,000. These figures, however, should not mislead one into thinking that in hardness and texture the Grafton stone resembles granite, for it does not.

The following analyses* show the composition of stone used on the new waterworks:

GRAFTON AND JOLIET STONE.

		Grafton.	Joliet.
Lime	$Ca O$	29.44	33.52
Magnesia.....	$Mg O$	17.81	10.93
Carbon dioxide.....	$C O_2$	45.32	40.69
Alumina and ferric oxide	$Al_2 O_3 + F_2 O_3$	4.25	3.95
Sulphuric anhydride...	$S O_3$	0.06	0.05
Silica.....	$Si O_2$	3.25	10.96
Organic matter and water		0.13	0.31
Total		100.26	100.41

*Wixford.

Limestone from Bedford, Ind., is largely used in this market. It is a massive stone, shading in color from buff to blue, the blue being considered superior. The following analyses * will show its composition :

BEDFORD STONE.

		Buff.	Blue.
Lime.....	Ca O.....	55.34	53.68
Magnesia.....	Mg O.....	0.40	0.71
Carbon dioxide.....	C O ₂	43.60	42.81
Alumina and ferric oxide	Al ₂ O ₃ +Fe ₂ O ₃	0.31	0.50
Insoluble, organic.....	.....	0.11	0.25
“ siliceous.....	.....	0.35	1.64
		100.11	99.59

The analysis shows that it is a pure limestone, and of practically the same composition as the St. Louis limestone.

Three-inch cubes of the same piece of stone which was analyzed, gave the following results : One cube of blue Bedford, crushing strength 6,090 lbs. per square inch ; one cube of buff crushed at 3,890 lbs. per square inch ; one cube of buff crushed at 3,140 lbs. per square inch.

The following table gives the breaking strength of beams sawed out of the same stone :

BEAMS OF BEDFORD STONE.†

	Dimensions in inches.			Central Breaking Load in lbs	Maximum Fibre Stress, lbs. per Sq. In.	Deflec- tion in Inches	Resistance.	
							Inch.	Lbs.
	b	h	l	w	$f = \frac{3wl}{2bh^2}$	d	Total $\frac{1}{2} wd$	Per Cu. In.
Blue	3.02"	4.0"	34.5	1,200	1290	0.024	14.4	0.0346
Buff	3.02"	3.0"	42	380	880	0.040	7.6	0.020

* Wixford.

†See note 9.

In the former beam the natural bed of the stone was thought to be transverse to the axis, while in the latter the natural bed was not known.

The following is an analysis* of Lake Superior red sandstone, which is largely used here in ornamental building work :

LAKE SUPERIOR SANDSTONE.

Carbonic dioxide.....	C O ₂	1.02
Silica.....	Si O ₂	0.22
Alumina and ferric oxide	Al ₂ O ₃ +Fe ₂ O ₃	1.52
Lime.....	Ca O.....	0.32
Magnesia.....	Mg O.....	0.06
Silica.....	Si O ₂	81.90
Alumina and ferric oxide	Al ₂ O ₃ +Fe ₂ O ₃	9.63
Lime.....	Ca O.....	0.38
Magnesia.....	Mg O.....	0.33
Soda.....	Na ₂ O.....	1.11
Potassa.....	K ₂ O.....	5.24

101.73

The table given below shows the density and porosity of a number of stones :

STONE.†

Kind of Stone.	Spec. Grav.	Wt. per Cu. Ft.	Per Cent. of Water Absorbed.
Red granite.....	2.64	165.0	....
" ".....	2.63	164.4	....
" " (surface).....	2.61	163.1	....
Gray granite.....	2.64	165.0	....
North St. Louis limestone..	2.65	165.6	....
Joliet stone.....	2.63	164.4	....
" ".....	2.65	165.6	....
" " (seamy).....	2.57	160.6	2.40
Grafton stone.....	2.52	157.5	....
Stone three miles north of	2.66	166.3	4.00
Chain of Rocks, quarry of	2.64	165.0	0.44
Wm. Vogelsson.....	2.64	165.0	0.65
Blue Bedford.....	2.49	155.4	1.13
Buff Bedford.....	2.19	136.7	1.61
Lake Superior sandstone...	2.10	131.0	5.69
			5.49

* Wixford.

† See note 10.

SAND.*

By far the greatest part of the sand used here is taken from the channel and bars of the Mississippi river.

Some experiments with such sand showed that:

Dry sand weighs 105 lbs. per cu. ft. and contains about 30 per cent. of voids. Sand settled by sprinkling in water weighs 112 lbs. per cu. ft., after deducting the weight of water in voids, *i. e.*, 112 lbs. of dry sand sprinkled into water will occupy one cubic foot of space. The specific gravity of the average particle is 2.60.

Three parts of sand and one part of Louisville cement will give three parts of mortar.

Two and one-half parts of sand and one part of Puzzolan cement (fine ground) will give two and one-half parts of mortar.

Any additional cement in either case will give an increased volume of mortar.

The experiments given below show the value of river sand for mortar.

The following tests were made with Dyckerhoff cement mixed with a sample of standard sand, such as is used in the official testing laboratories of Germany, and also with Mississippi river sand:

	No. of samples	Age—days.	Tensile strength, lbs. per sq. in.	No. of samples.	Age—days.	Tensile strength, lbs. per sq. in.
German standard sand.....	5	7	182	5	28	220
Mississippi river sand.....	10	7	249	10	28	257

* See Note 11.

The above tests were all made with one part of cement to three parts of sand by weight.

The following tests were also made with one part of Dyckerhoff cement to three parts of sand by weight. Three samples of each kind were made and all exposed one day in air and six days in water:

Sand Tests.		Average Tensile strength lbs. per sq. in.
Where obtained.		
Kaw river.....		218
Bar opposite city.....		184
Meramec river		197
German standard		208
Mississippi (passing a No. 20 but not a No. 30 sieve).....		225
All of these samples were clean and coarse.		

BRICK, CLAY PIPE, Etc.*

Coming now to artificial or manufactured stone, we find our city well provided with suitable material. In the hills are found unlimited quantities of yellow brick clay, which is very plastic when tempered. An air-dried sample of this clay gave the following analysis:†

Common Yellow Brick Clay.	
Loss by ignition.....	4.25
Silica	77.87
Oxide of iron	3.84
Alumina	9.89
Lime	1.60
Magnesia.....	0.44
Sulphuric acid.....	traces
	97.89

*See Note 13.

†By Mr. T. J. Caldwell.

To show the density of St. Louis brick, the following table of tests is given. The brick are numbered in the order of their hardness, as shown by the pitch of the sound given by the brick when struck, No. 1 being the softest salmon and No. 26 the hardest paving brick. The specific gravity was determined by dividing the dry weight of the brick by the difference between the wet weight in air and the wet weight in water:

RED BRICK.***Density, etc.**

No.	Spe. Grav.	Wt. per cu. ft.	Per cent. of water absorbed	Kind of brick.	No.	Spe. Grav.	Wt. per cu. ft.	Per cent. of water absorbed	Kind of brick.
1	1.49	93.1	21.3	Hand.	14	1.93	123.7	8.5	Hammer.
2	1.61	100.6	21.0	Pressed.	15	1.68	105.0	15.8	Hand.
3	1.83	114.4	14.1	"	16	1.91	119.4	11.3	Pressed.
4	1.79	111.9	15.3	"	17	1.69	105.6	15.0	Hand.
5	1.83	114.4	13.5	"	18	1.83	114.4	13.0	Pressed.
6	1.54	96.3	20.0	Hand.	19	1.96	122.5	9.4	"
7	1.69	105.6	18.1	Pressed.	20	1.88	117.5	12.3	"
8	1.72	107.5	17.1	"	21	1.82	113.8	13.3	"
9	1.72	107.5	14.2	Hand.	22	1.93	120.6	9.2	"
10	1.81	113.1	14.8	Pressed.	23	1.85	115.6	13.0	"
11	1.86	116.2	12.3	"	24	2.01	125.6	8.2	Hammer.
12	1.96	122.5	9.6	Hammer.	25	1.88	117.5	11.0	Pressed.
13	1.85	115.6	12.4	"	26	2.18	136.3	4.7	"

The following table will explain itself:

SIZE AND WEIGHT OF ST. LOUIS BRICK.†

As Shown by the Measurement of Twelve Bricks of Each Kind from Four Different Brick Yards.

KIND OF BRICK	LENGTH.			WIDTH.			THICKNESS.			SPECIFIC GRAVITY.	
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Paving	8 $\frac{3}{8}$	8	8 3-16	4 $\frac{1}{4}$	3 $\frac{3}{8}$	4	2 5-16	2 1-16	2 $\frac{1}{8}$	2.18	1.95
D'k. red	8 $\frac{1}{2}$	8 $\frac{1}{4}$	8 5-16	4 $\frac{1}{4}$	4	4 $\frac{1}{8}$	2 $\frac{3}{8}$	2 $\frac{3}{8}$	2 3-16	1.95	1.80
Lgt. red	8 $\frac{1}{2}$	8 $\frac{3}{8}$	8 7-16	4 $\frac{1}{4}$	4	4 3-16	2 $\frac{3}{8}$	2 $\frac{1}{8}$	2 $\frac{1}{4}$	1.80	1.65
Salmon	8 $\frac{3}{8}$	8 $\frac{3}{8}$	8 $\frac{1}{2}$	4 $\frac{3}{8}$	4 3-16	4 $\frac{1}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 5-16	1.65	1.48

* See Note 12.

† See Note 12.

Stock bricks closely piled will measure about 51 cubic feet per 1,000 brick.

St. Louis brick are of ample strength for ordinary building purposes. Tests of red brick made for the Eads bridge show a crushing strength of from 2,000 to 7,500 pounds per square inch.

Straight, hard brick, such as are used in engineering work, can usually be bought at from seven to ten dollars per thousand.

Vitrified brick are not made extensively in the city.

Eleven samples of vitrified or "blue" brick made here were tested and found to have a specific gravity of 1.99 to 2.11, and weighed from 124.4 to 131.9 pounds per cubic foot. These brick absorb water very slowly. After immersion for three months, they were found to have absorbed from 2.33 to 5.53 per cent. of water by weight.

These brick are quoted at about twelve dollars per thousand, common brick size.

Vitrified clay sewer pipe are of material similar to the above-mentioned vitrified brick. Two samples of pipe made in St. Louis were tested, with the following results:

Vitrified Clay Pipe.

Color of fracture.	Specific gravity	Per cent. of absorption by weight when immersed in water.		
		24 hours.	72 hours.	96 hours.
Dark	2.14	3.27	3.74	3.74
Light.	2.19	2.91	2.91	2.91

Experiments made at the Rose Polytechnic Institute showed that tested by hydraulic pressure American

vitrified sewer pipe have an average tensile strength of at least 600 pounds per square inch.

The manufacturer's price list given below contains useful information in regard to sewer pipe as it is made in this city.

The present discount for straight pipe is about 75 per cent.

Standard Vitrified, Salt Glazed Sewer Pipe.

Inside Diameter.	Straight Pipe, per foot.	Curves and Elbows, each.	T & Y Junctions, each.	Weight per foot.	Area in inches.	No. of feet in Car Load of 12 tons.	Inside Diameter.	Straight Pipe, per foot.	Curves and Elbows, each.	T & Y Junctions, each.	Weight per foot.	Area in inches.	No. of feet in Car Load of 12 tons.
In.	\$0 15	\$0 50	\$0 60	Lbs.			In.	\$0 90	\$3 25	\$3 60	Lbs.		
3				7	7	3430	14				52	154	460
4	20	60	80	9	12	2660	15	1 00	3 75	4 00	57	177	420
5	25	75	1 00	12	19	2000	16	1 20	4 25	4 80	66	201	364
6	30	1 00	1 20	16	28	1500	18	1 50	4 75	6 00	82	254	290
7	35	1 25	1 40	19	39	1260	20	1 75	5 75	7 00	94	314	254
8	40	1 50	1 60	23	50	1040	21	1 90	6 25	7 60	100	345	240
9	50	1 75	2 00	28	64	860	22	2 10	7 00	8 40	110	380	218
10	60	2 10	2 40	33	78	730	24	2 50	8 00	10 00	130	452	180
12	75	2 75	3 00	42	113	570							

A common fire brick is nominally $2\frac{1}{2} \times 4\frac{1}{2} \times 9$ inches. An average brick will measure $2\frac{1}{2} \times 4\frac{3}{8} \times 8\frac{7}{8}$ inches. Our brick contains 100 cubic inches and weighs 7 pounds, or 121 pounds per cubic foot. These brick, of a good quality, may be bought in St. Louis for from fifteen (\$15.00) dollars to twenty-five (\$25.00) dollars per thousand.

The manufacture of blocks for fire-proofing buildings from St. Louis clays has of late become quite extensive. This material is more or less porous, and ranges in density from that of fire brick to about two-thirds of that value. Made up into hollow-arch blocks for floors;

The "loss by ignition" shown by any sample of cement, which may be determined in a few minutes, is a pretty fair indication of its condition and consequent value. Nos. 1, 2 and 3 were cement sampled out of barrels on the street, intended for street reconstruction.

No. 1, by briquette test, was found to be extremely poor, and the loss of 19.22 per cent. by ignition is an excellent index of its poor quality. A number of ignition tests of Louisville cement showed that when the loss was as much as 10 per cent. the cement could be pronounced very inferior.

No. 4 was sent direct from Louisville by request.

No. 5 was sampled at the warehouse.

No. 6 was sent by the local cement agent from stock on hand.

The City Sewer Department has required Louisville cement to stand a tensile test of sixty pounds per square inch, after thirty minutes in air and twenty-four hours in water, with but few rejections.

On the Water Works Extension Louisville cement has been required to have a tensile strength of ninety pounds per square inch, after two hours in air and forty-eight hours in water, and to have such fineness that 90 per cent. will readily pass through a sieve having 2,500 meshes per square inch. A considerable proportion of the cement failed to pass these tests, especially that for fineness.

A Louisville cement barrel has a capacity of 3.5 cubic feet, while a Rosendale barrel has a capacity of 3.8 cubic feet, and an ordinary Portland barrel has 3.3 cubic feet capacity.

Weight Per Barrel :

	Louisville.	Portland.
Empty barrel.....	20 lbs.	20 lbs.
Cement.....	265 "	380 "
Full barrel.....	285 "	400 "

CONCRETE.

The table given below shows the results of some experiments to determine the cross breaking strength of concrete made in the form of beams.

These beams were 10 inches square and 5 feet long. They were made of the ordinary broken limestone and a clean, sharp river sand. They were made up in trenches November 25-7, 1885, and left in the ground till April, 1886. Then they were exposed to the weather, with board covering, till tested on October 29, 1887. They were, therefore, nearly two years old when tested. They were placed on supports, 60 inches apart, and loaded in the middle in a Riehle testing machine.

The cement used in the beams tested neat as follows :
Louisville (Hulme-Star brand), 30 min. in air

 " and 66 hrs. in water..... 122 lbs.
Alsen's Portland, 24 hrs. in air, 50 hrs. in
 water..... 228 "

Cumberland (American) Portland, same time.. 134 "

White's Portland, 24 hrs. air and 48 hrs. water, 109 "

 " " 3 months, 13 days in air.... 505 "

The tests of the beams gave the following results, the modulus in cross-breaking being computed by the ordinary formula, viz.: $f = \frac{3}{2} \frac{wl}{bh^2}$.

Where w—breaking load on beam.

 " l—length of beam in inches.

 " b—breadth of beam in inches.

 " h—depth of beam in inches.

TESTS OF CONCRETE BEAMS 10 INCHES SQUARE AND 60 INCHES LONG.*

COMPOSITION OF BEAMS.			Breaking load.	Cross- breaking modulus.
Cement.	Sand.	Broken stone.		
Louisville..... 1½	3	6	1,600	140
"..... 2	4	9	2,050	206
"..... 2	4	9	3,600	324
Alsen's Port..... 2	5	9	3,600	350
"..... 1½	6	10	4,200	378
+Cumberland Port.... 2	5	9	2,600	234
"..... 1½	6	10	800	72
White's Port ... 2	5	9	4,300	356
"..... 1½	6	10	4,400	396

The following table shows some experiments made to determine the strength of Louisville cement concrete in compression for different proportions of ingredients.

Six concrete blocks, eight inches by eight inches by twelve inches, were made with Queen City Louisville cement. The blocks were crushed when six months old. They had a cross section of about sixty square inches:

CRUSHING STRENGTH OF LOUISVILLE CEMENT CON- CRETE.†

PARTS BY VOLUME.			Crushing strength in pounds per square inch.	PARTS BY VOLUME.			Crushing strength in pounds per square inch.
Cement	Sand.	Stone.		Cement	Sand.	Stone.	
1	2	5	410	1	2	4	410
1	2	5	500	1	1	3	650
1	2	4	340	1	1	3	640

STRENGTH OF GRANITOID BEAMS.‡

Made of Crushed Granite and Portland Cement.

Each result is the mean of two tests on beams 4" x 4" x

* See Note 14.

† American cement.

‡ See Note 14.

§ See Note 15.

18" long, broken by a load in the middle. The strength in pounds per square inch is computed from the formula

$$f = \frac{3}{2} \frac{wl}{bh^2}$$

Mixture.	Age in weeks.	FINE GRANITE.		COARSE GRANITE.	
		Strength per square in. (f.)	Mean.	Strength per sq. in. (f.)	Mean.
3 to 1	6	323	336	447	465
"	8	315		497	
"	10	370		452	
4 to 1	6	274	306	434	449
"	8	242		439	
"	10	401		473	
5 to 1	6	233	353	377	436
"	8	289		445	
"	10	539		485	
6 to 1	6	337	364	472	481
"	8	339		461	
"	10	416		511	

The following data on cost of concrete* are taken from notes regarding Portland cement concrete put on the haunches of the waterworks conduit arch. All the materials were close to the work; the concrete was mixed by hand and shoveled from the bed into place. The amount of concrete used averaged 0.487 cubic yards to the running foot. The gang of men consisted of one foreman at \$3.00 and twelve laborers at \$1.75 each, \$21.00=\$24.00. This gang put in 38 cubic yards, or 78 linear feet, per day; hence, cost of mixing averaged \$0.63 1-6 per cubic yard.

The specifications call for materials in the proportions: cement, 1; sand, $2\frac{1}{2}$; rock, 5.

*See Note 5.

On a 156' section of work there were used

67 barrels cement,	- @ \$3.00..	\$201.00
25 cubic yards sand,	- @ 75..	18.75
50 cubic yards crushed rock,	@ 2.00..	100.00
		\$319.75

This made 76 cubic yards of concrete.

Hence, cost of material per cubic yard.....	\$4.21	.
“ “ mixing.....	63	1-6

Total cost, not including tools or general
superintendence..... \$4.84

To compare with the above we have the following case, which shows the cost of mixing and depositing concrete in the foundations of pier No. 4 of the Maline Creek aqueduct bridge.

The concrete was composed of one part of Louisville cement, two parts of sand and six parts of rock. The cement and sand were thoroughly mixed dry, then with water.

One-half of the rock was deposited on another bed and about one-half of the mortar thrown over it; the rest of the rock was deposited on this and the remainder of the mortar thrown on it. The whole mass was then turned three times by shoveling into piles. It was then shoveled into the boxes for lowering it into place.

Foreman,	3 days,	@ \$3.33.....	\$10.00
“	3½ “	@ 3.00.....	10.50
Laborers,	26.4 “	@ 1.75.....	46.20
Engineers,	3.1 “	@ 2.50.....	7.75
Engine, etc.,	3.1 “	@ 2.00.....	6.20
Teams,	3½ “	@ 3.50.....	12.25
Coal,	30 bu.,	@ .09.....	2.70
			\$95.60

Cubic yards of concrete.....	99.196
Cost per cu. yd. for mixing and deposit- ing in place.....	\$0.965

To show the cement required per cubic yard of concrete, the following is given:

The six foundations for Maline Creek aqueduct bridge are made of concrete composed of one part of Louisville cement, two parts of sand and six parts of rock.

Total cu. yds. of concrete.....970.672

“ barrels of cement in concrete.....854.

Cu. yds. of concrete to a barrel of cement. 1.14

Barrels of cement to a cu. yd. of concrete. 0.88

On the waterworks conduit where the proportions were two parts of Portland cement, five parts of sand and ten parts of broken stone, a barrel of cement would usually make from 1.10 to 1.20 cubic yards of concrete.

The floor of the conduit is covered with a three-inch layer of granitoid, made in the usual manner with a smooth finish. A barrel of cement laid from 42 to 72 square feet of granitoid, averaging about 50 square feet. A ton of crushed granite will lay about 66 square feet and costs about \$2.50 in the city.

STONE MASONRY.*

To show the amount of cement required for stone masonry, we have the following notes on the Louisville cement used in the piers of the Maline Creek aqueduct bridge. The mortar was one of cement and two of sand by volume:

*See Note 16.

Piers Nos. 1 and 6.

Size of piers, 11' x 19.5'. Average sizes of stones, about 10 cubic feet. Stones cut to half-inch joints. The backing was about one-fourth of the contents.

Pier No.	Cu. yds. masonry.	Bbbs. cement.	Bbbs. cement per cu. yd.
1	31.75	23	0.72
6	29.1	17	0.58
	<u>60.85</u>	<u>40</u>	<u>0.66</u>

Piers Nos. 2 and 5.

Size of piers, 11' x 19.5'. Average size of stones, about 13 cubic feet. Backing about one-fourth of the contents.

Pier No.	Cu. yds. masonry.	Bbbs. cement.	Bbbs. cement per cu. yd.
2	67.7	37.5	0.55
5	63.4	24.0	0.35
	<u>131.1</u>	<u>61.5</u>	<u>0.47</u>

Piers Nos. 3 and 4.

Size of piers, 4' x 19.5'. Average size of stones, about 15 cubic feet. These are really dimension stones, without any backing.

Pier No.	Cu. yds. masonry.	Bbbs. cement.	Bbbs. cement Per cu. yd.
3	42.92	8	0.19
4	43.08	9	0.21
	<u>86.00</u>	<u>17</u>	<u>0.20</u>

On the recent work of the waterworks extension in different classes of stone masonry laid in Portland cement in the proportion of two parts of cement to five parts of sand, the amount of cement used per cubic yard of masonry has varied from 0.24 to 0.65 barrels, according to thickness of the joints, amount of backing, etc.

The following notes will give a rough idea of the cost of setting stone:

Cost of setting stones in Pier No. 4, Maline Creek Bridge.

Size of pier, 4' x 19.5', with footing course 5, x 20.5; 14.52' in height. Average size of stones, about 15 cubic feet. Time of setting, 21 hours.

Foreman,	2 $\frac{5}{8}$	days,	@	\$4.50.....	\$ 11.25
"	1 $\frac{1}{2}$	"	@	3.33.....	5.00
Stonemason,	2 $\frac{5}{8}$	"	@	4.00.....	10.50
Labor,	16.9	"	@	1.75.....	29.58
Teams,	1 $\frac{1}{2}$	"	@	3.50.....	5.25

Total cost.....\$ 61.58

Total number of cubic yards.....43.08

Cost of setting per cubic yard.....\$1.42

In the new inlet tower at the Chain of Rocks, the actual cost of laying the masonry, not including any materials, was about \$2.25 per cubic yard. This was heavy cut granite and limestone, laid in courses, with Grafton stone backing.

The following table shows the contract prices of stone masonry per cubic yard on the waterworks extension to 1892:

COST OF STONE MASONRY.

	Stone used.	Maximum.	Minimum.
Dimension cut as in arches, etc.. B	Grafton.	\$ 29 00	\$ 28 00
Dimension cut as in arches, etc....	Bedford.	45 00 A	22 50 B
Coursed and dimension cut.....	Granite.	60 00 A	39 50 B
Coursed and dimension cut (engine foundation)..... A	Grafton.	29 85	.....
Coursed cut in gate chambers, etc..	Bedford.	30 00 A	15 50 B
Coursed cut in gate chambers, etc..	Grafton.	25 00 A	11 40 B
Coursed cut in gate chambers, etc. A	Joliet.	20 00	.....
Heavy retaining walls, broken range..... A	Grafton.	12 00	7 50
Foundation walls, rubble..... B	Grafton.	6 75	.....
Foundation walls, rubble..... A	St. Louis.	5 00	.....

A Signifies Portland Cement.

B Signifies Louisville Cement.

BRICK MASONRY.

The table given below shows the results of some experiments to determine the cross-breaking strength of brick masonry. The beams were sixty inches long between supports, twelve inches high and eight, and one-half inches wide. The modulus in cross-breaking was computed by the ordinary formula, viz.: $f = \frac{3}{2} \frac{wl}{bh^2}$

Where w = center breaking load.

l = length between supports in inches.

b = breadth in inches.

h = depth in inches.

STRENGTH OF BRICK MASONRY BEAMS.*

Two Years Old.

COMPOSITION OF MORTAR.		Breaking Load, pounds.	Cross-breaking modulus f . Lbs. per sq. inch.
Cement.	Sand.		
Louisville.....1	1	4,000	274
Alsen's Port.....1	3	2,300	158

The following data are taken from waterworks conduit construction:†

The work consisted of two side walls 2' 6" high and 13" thick, covered by an arch of 9' inside diameter and 13" thick. The arch was turned on centering in five lengths of 16 feet each. The brick was of average size for St. Louis, and laid with push joint in the 13" wall—the joints averaging about $\frac{1}{2}$ ".

* See Note 14.

† See note 17.

Equivalent time of men as follows:

166 bricklayers, 1 day each, @ \$4.40= \$730.40

285 laborers, 1 day each, @ \$2.00...= 570.00

Total cost of labor for 1,065 cu. yds. \$1,300.40

Whence cost of laying one cubic yard, including moving centers=\$1.221.

Number of brick (by count) in one linear foot of conduit, 400.

Number of brick in wall 2, 6" high, 1' long, 13" thick, 48.4.

Number of brick in 1' of arch described above, 291.7.

Number of brick in a cubic yard, 452, without allowance for waste, which was about 2 per cent.

To lay one cubic yard of brick masonry, with joints of $\frac{1}{2}$ ", there is required 452 brick, .55 barrels of cement and .20 cubic yards of sand. Mortar composed of one part Portland cement and two and one-half parts sand.

Other notes from the conduit work show that the amount of Portland cement used per cubic yard of brick masonry ranges from 0.55 to 0.74 bbl., and is usually about 0.60 bbl.

Other actual counts of the brick in a wall showed 408 and 422 brick per cubic yard, respectively.

On one section of the conduit each bricklayer averaged 3,243 brick per day.

In the inlet tunnel at the Chain of Rocks, where Portland cement mortar, of the same proportions, was used, each cubic yard of brick work required 330 brick and 0.97 bbls. of cement. The cost of laying, not including materials, was about \$2.43 per cubic yard.

CIRCULAR BRICK SEWERS.*

The sizes of brick sewers, their construction and

*See Note 3.

hydraulic factors, length built in St. Louis since 1880, and average cost per foot are shown by the accompanying table.

The cement used was mostly Louisville.

In the table the lengths built as district and public sewers are shown separately, to show the effect of difference in mode of payment. District sewers are paid for by special tax bills, issued after the work is fully completed; the contractor assuming all risks and costs of collection. Public sewers are paid for in cash, by monthly installments, as the work progresses. The cost per foot includes rock and other difficult work, hence the apparent irregularities in cost.

Hydraulic factor C is given for brick sewers by formula, $C = \frac{181.46}{0.548 \sqrt{V_r}}$

Diam.	HYDRAULIC FACTORS FOR MAXIMUM CAPACITY.				BUILT SINCE '80, IN ST. LOUIS			
	Perim. Feet.	Area, Sq. Feet.	H.M.D. Feet.	C.	DISTRICT.		PUBLIC.	
					Length Feet.	Cost.	Length Feet.	Cost.
2'6"	6.545	4.767	0.768	110.5	7,105	\$ 3 05	790	\$2 74
3'0"	7.854	6.865	0.874	114.4	.....	.....	2,150	3 00
3'6"	9.163	9.173	1.020	117.7	.....	.....	3,521	3 87
4'0"	10.472	12.204	1.168	120.4	.....	.....	4,525	5 43
4'6"	11.781	15.444	1.311	123.0	.....	.....	2,537	4 42
5'0"	13.090	19.068	1.457	124.8	.....	.....	1,534	6 21
5'6"	14.399	23.070	1.602	126.9	402	7 32	2,389	8 47
6'0"	15.707	27.458	1.748	128.3	583	7 86	1,893	8 00
6'3"	16.362	29.80	1.821	129.0	630	7 84	.....	.....
6'6"	17.017	32.23	1.894	129.8	1,521	12 48	549	7 57
7'0"	18.326	37.374	2.039	131.1	.....	.....	3,312	9 93
7'3"	18.980	40.09	2.112	131.8	.....	.....	2,565	6 86
7'6"	19.635	42.90	2.185	132.6	.....	.....	2,654	8 01
7'9"	20.290	45.81	2.258	133.2	597	9 95	.....	.....
8'0"	20.945	48.818	2.331	133.5	361	10 66	6,018	10 72
8'3"	21.599	51.91	2.404	134.3	508	11 43	.....	.....
8'6"	22.254	55.11	2.476	134.8	2,848	17 63	1,036	8 40
9'0"	23.562	61.78	2.622	135.8	.....	.....	.....	.....
9'6"	24.871	68.84	2.768	136.5	.....	.....	188	13 65
10'0"	26.180	76.274	2.913	137.6	.....	.....	.....	.....
10'6"	27.489	84.09	3.059	138.3	.....	.....	7,302	16 89
12'0"	31.415	109.834	3.496	140.3	.....	.....	1,382	17 16

A useful and easily remembered rule for roughly estimating the cost of brick work where no ornament is required, is that a cubic yard of brick work will cost about as much as a thousand of brick.

PIPE SEWERS.

The following table shows the cost, etc., of the city pipe sewers, which are made of vitrified clay pipe:

Clay Pipe Sewers.*

Diam. inches.	HYDRAULIC FACTORS FOR MAXIMUM CAPACITY.				BUILT SINCE 1880.	
	Perim., Feet.	Area. Square Ft	H. M. D., Feet.	C.	Length, Feet.	Cost.
12	2.618	0.763	0.291	99.8	177,555	\$ 0 91
15	3.272	1.192	0.364	105.2	145,945	1 04
18	3.927	1.716	0.437	109.5	30,212	1 30
24	5.236	3.051	0.583	116.2	138	2 67

TIMBER.†

The experience of the City Bridge Department has been in the case of bridge floors, that when the timber is subjected to wear by heavy traffic, oak will last about twice as long as white pine, but where there is no wear the pine will last about as long as the oak. In the bridges of Forest Park, yellow pine has not lasted as well as white pine.

On the Duncan avenue bridge, over the Wabash R. R. tracks, yellow pine joists were found to be perfectly sound after sixteen years. It is supposed that the drying effect of the smoke from the locomotives preserved them from decay.

On the floor of the Jefferson avenue bridge sawed gum blocks lasted eight years, but gave trouble by swelling.

*See Note 3.

†See Note 18.

On the Eighteenth street bridge sawed white pine blocks were entirely gone in five years. Some of these blocks were originally treated with chloride of zinc, but these lasted no better than the untreated.

The bridge was again paved with white pine blocks, and after one year they are rotting badly.

On the Grand avenue bridge, white pine blocks, untreated, have lasted three years.

Under the rails of the incline of the temporary pumping plant of the waterworks, yellow pine ties and stringers were badly decayed in five years. These timbers were embedded in cinders and submerged at high water. The timbers at the lower end of the incline, which were embedded in mud, were still sound.

CAST IRON.*

The tensile strength of cast iron, as obtained from St. Louis iron foundries is from 17,000 to 30,000 lbs. per square inch.

The best practice is, for ordinary castings, 20,000 lbs.; for the best, 25,000 lbs.

The crushing strength varies from 50,000 to 130,000 lbs. per square inch, but should not be specified, since the irons very strong in compression are apt to be too hard and brittle for finishing and for service.

The cross-breaking strength varies from 25,000 to 50,000 lbs. per square inch on the extreme fibre, when computed from the formula for rectangular beams :

$$f = \frac{3}{2} \frac{wl}{bh^2} \text{ where}$$

f —stress per sq. in., in lbs.

w —load on center in lbs.

l —length between supports, in inches.

b —breadth of beam, in inches.

h —depth of beam, in inches.

*See Note 15.

For ordinary castings the metal should stand a breaking load, f , equal to 36,000 lbs. per square inch ; or, in other words, a beam 24 inches long and 1 inch square should carry a load of 1,000 lbs. at its center.

If stronger iron is required, a value of f , equal to 45,000 lbs. may be obtained, or a beam 1 inch square and 30 inches long, should carry 1,000 lbs. at its center.

The resilience of a body is its property of absorbing the energy of a blow.

Its elastic resilience is measured by the quantity of energy it may absorb and fully recover, or absorb without being strained beyond its elastic limit.

Its total resilience is measured by the total energy it may absorb without breaking.

Since cast iron usually breaks by some kind of shock or blow, its resilience is much more important than its strength. Furthermore, the resilience is very much more uncertain than the strength. It follows that a test for resilience is many times more necessary than a test for strength.

The simplest method of finding the resilience of cast iron is by means of a cross-breaking test. The total resilience of a rectangular bar in cross-breaking is one-half the product of the breaking load into the deflection of the middle point. If we now divide by the weight of the bar in pounds, we obtain the cross-breaking resilience of the iron per pound of metal.

This result varies from ten, for the most brittle and worthless irons, to sixty for the toughest and strongest.

In good, local practice here the iron for ordinary castings will have a resilience of not less than twenty-five inch-pounds per pound of metal, while that for ma-

chinery castings will run over thirty-five inch-pounds per pound of metal. The resilience in inch-pounds per pound of metal is the best measure of the resistance of the iron to shocks and blows.

BRONZE.*

The following table shows the character of alloys made here. The composition designated as gun metal is composed of eighty-five parts of copper, ten of tin and five parts of zinc, and is used for bearing parts of water valves, gates, etc. These tests were made at different times and the bars were from different St. Louis foundries taken in the course of inspection :

Kind of bronze.	Tensile strength, lbs. per square in.	Length in inches of portion measured	Per cent. of elongation
Phosphor bronze.....	29,950	8	7.37
Phosphor bronze.....	25,180†	8	4.37†
“ “	34,110	8	20.0
“ “	30,400	10	12.5
“ “	31,000	10	8.1
“ “	32,900	6	19.7
“ “	32,500	6	16.7
Gun metal.....	23,800	10	3.7
“	22,000	10	3.7
“	29,100	6	10.0
“	29,000	6	10.5

*See Note 19.

† Flaws.

NOTES.

NOTE 1.—Contributed by E. D. Meier, Mem. Am. Soc. C. E., President of Heine Boiler Co., Past President of the Engineers' Club.

NOTE 2.—These notes were contributed by F. E. Nipher, Professor of Physics, Washington University, formerly Director of Missouri Weather Service, Past President of the Engineers' Club.

NOTE 3.—Contributed by R. E. McMath, Mem. Am. Soc. C. E., Sewer Commissioner of St. Louis, Past President of the Engineers' Club.

NOTE 4.—Compiled from several authorities by the Chairman of the Committee on Local Engineering Data.

NOTE 5.—The notes on cost of foundations and excavation and concrete were furnished mainly by Thos. B. McMath, C. E., and C. V. Mersereau, Mem. Am. Soc. C. E.; both Division Engineers on the Waterworks Extension.

NOTE 6.—Contributed by Jas. A. Seddon, C. E., Div. Engr. Waterworks Extension.

NOTE 7.—Computed by W. S. Henry, C. E., Asst. Engr. Waterworks Extension.

NOTE 8.—The river data were furnished mainly by J. A. Seddon and Geo. H. Johnson.

NOTE 9.—These tests were made for the Club by J. B. Johnson, C. E., Professor of Civil Engineering, Washington University.

NOTE 10.—The greater part of this table was furnished by S. F. Burnet, C. E., Asst. Engr. Waterworks Extension.

NOTE 11.—The notes on sand were taken from the Waterworks Extension Records by the Chairman of the Committee.

NOTE 12.—Contributed by S. F. Burnet, C. E., Div. Engr. Waterworks Extension.

NOTE 13.—Collected from various sources by the Chairman of the Committee.

NOTE 14.—These tests were made by Prof. Johnson for the Water Department.

NOTE 15.—Contributed by J. B. Johnson, Mem. Am. Soc. C. E., Prof. of Civil Engineering, Washington University, past President of the Engineers' Club.

NOTE 16.—Contributed largely by C. V. Mersereau, Mem. Am. Soc. C. E., Div. Engr. Waterworks Extension.

NOTE 17.—By Thos. B. McMath, C. E., Div. Engr. Waterworks Extension.

NOTE 18.—The bridge experience was obtained from Carl Gayler, Mem. Am. Soc. C. E., City Bridge Eng.

NOTE 19.—These data were taken from the Water Department Records by the chairman of the committee.

NOTE 20.—*Chemical analyses* were obtained from Thos. J. Caldwell, C. E., Inspector and Chemist of St. Louis Street Department, and from Jno. F. Wixford, Chemist of St. Louis Water Department.

NOTE 21.—The tables of fuels and boiler tests were supplied by W. B. Potter, E. M., Professor of Mining and Metallurgy, Washington University, and Manager of St. Louis Sampling and Testing Works; Past President of the American Inst. of Mining Engineers, and Past President of the Engineers' Club.

COMMITTEE ON LOCAL ENGINEERING DATA.

J. B. JOHNSON, Mem. Am. Soc. C. E., Professor of Civil Engineering, Washington University, St. Louis, Past President Engineers' Club.

ROBT. MOORE, Mem. Am. Soc. C. E., Chief Engineer of Merchants' Terminal R. R. of St. Louis, President of the Engineers' Club.

S. BENT RUSSELL, Chairman, Mem. Am. Soc. C. E., Assistant Engineer in Charge of St. Louis Water Works Extension.

TABLE I.

Anal- ysis No.	NAME OF COAL AND LOCALITY.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	British Heat Units or Cal- orific Power per lb. of Coal.	Average Cal- orific Power for each Group.	Theoretical Evaporation from and at 212° F. in lbs. of Water.	Average The- oretical Evap. for each Group in lbs. of Water.
1	Gillespie Coal—Macoupin Co., Ill.....	12.61	30.58	45.27	11.54	1.45	9,739	9,739	10.09	10.09
2	St. John's Coal—Perry Co., Ill.....	9.82	28.35	45.77	16.08	2.06	9,765	9,765	10.10	10.10
3	" " " " " "	13.60	24.46	43.54	15.40	1.83	9,828	9,828	10.18	10.18
4	Nut Coal, Vulcan, St. Clair Co., Ill.	7.44	30.86	45.09	16.61	1.32	9,450	} 10,038	9.78	} 10.39
5	" " " " " "	10.30	27.91	48.99	12.80	0.71	10,626		11.00	
6	St. Clair, Ill.	7.80	30.69	39.68	21.83	9.62	9,261	} 10,067	9.58	} 10.42
7	" " " " " "	10.25	33.10	41.79	14.86	6.92	10,294		10.65	
8	" " " " " "	11.15	34.19	44.94	9.72	4.27	10,647	} 10,080	11.02	} 10.44
9	St. Bernard—Ind. & St. Louis R'y.....	14.36	30.86	48.39	6.39	1.38	10,080		10.44	
10	Girard Coal, Macoupin Co., Ill.....	9.70	34.39	45.76	10.15	3.49	9,954	} 10,112	10.30	} 10.46
11	" " " " " "	8.90	32.25	42.89	15.96	8.10	10,269		10.63	
12	Collinsville, Madison Co., Ill.....	9.20	45.89	31.57	13.34	5.34	10,143	10,143	10.50	10.50
13	Heintz Bluff, St. Clair Co., Ill.....	8.95	37.81	48.24	5.00	3.27	10,332	10,332	10.69	10.69
14	Oakland Coal, St. Clair Co., Ill.....	8.30	34.40	43.12	14.18	4.42	10,395	10,395	10.76	10.76
15	Texas Coal, Ft. Worth.....	14.42	30.03	42.53	13.02	1.47	9,450	} 10,426	9.78	} 10.79
16	" " " " " "	4.60	34.72	49.27	11.41	1.56	11,403		11.80	
17	Duquoin, Jupiter, Perry Co., Ill.....	11.30	30.31	49.91	8.48	0.91	10,710	10,710	11.08	11.08
18	Trenton Coal, Clinton, Ill.....	13.34	30.39	51.96	4.31	0.92	10,584	} 10,915	10.96	} 11.30
19	" " " " " "	9.95	31.04	52.03	6.98	1.04	11,245		11.63	
20	Streator Coal, La Salle Co., Ill.....	12.01	35.32	48.78	3.89	2.38	11,403	11,403	11.80	11.80
21	Big Muddy, Jackson Co., Ill.....	7.39	28.28	53.87	10.46	0.98	11,466	} 11,592	11.87	} 12.00
22	" " " " " "	6.12	30.95	53.74	9.19	1.22	11,529		11.93	
23	" " " " " "	5.85	31.84	55.72	6.59	2.92	11,781	} 11,939	12.19	} 12.35
24	New Mexico Coal.....	2.35	35.53	50.24	11.88	0.61	11,756		12.17	
25	Arkansas (A), Coal Hill, Johnson Co....	1.70	14.60	74.91	8.79	3.04	11,812	11,812	12.22	12.22
26	Indian Territory, Atoka.....	6.66	35.42	51.32	6.60	3.73	11,088	} 11,939	11.47	} 12.35
27	" " Choctaw Nation.....	1.59	23.31	66.85	8.25	1.18	12,789		13.23	
28	Arkansas (B), Huntington Co.....	1.30	18.95	71.51	8.24	0.78	11,756	} 12,035	12.17	} 12.49
29	" " " " " "	1.30	18.90	73.15	6.65	0.75	11,907		12.32	
30	" " " " " "	1.27	18.89	71.74	8.10	0.65	12,537	} 12,600	19.97	} 13.03
31	Tennessee Coal.....	2.02	32.14	58.96	6.88	0.88	12,600		13.03	
32	Pittsburgh Coal, Pa., (av. of 5 lots).....	1.80	35.34	54.94	7.92	1.97	13,104	13,104	13.46	13.46

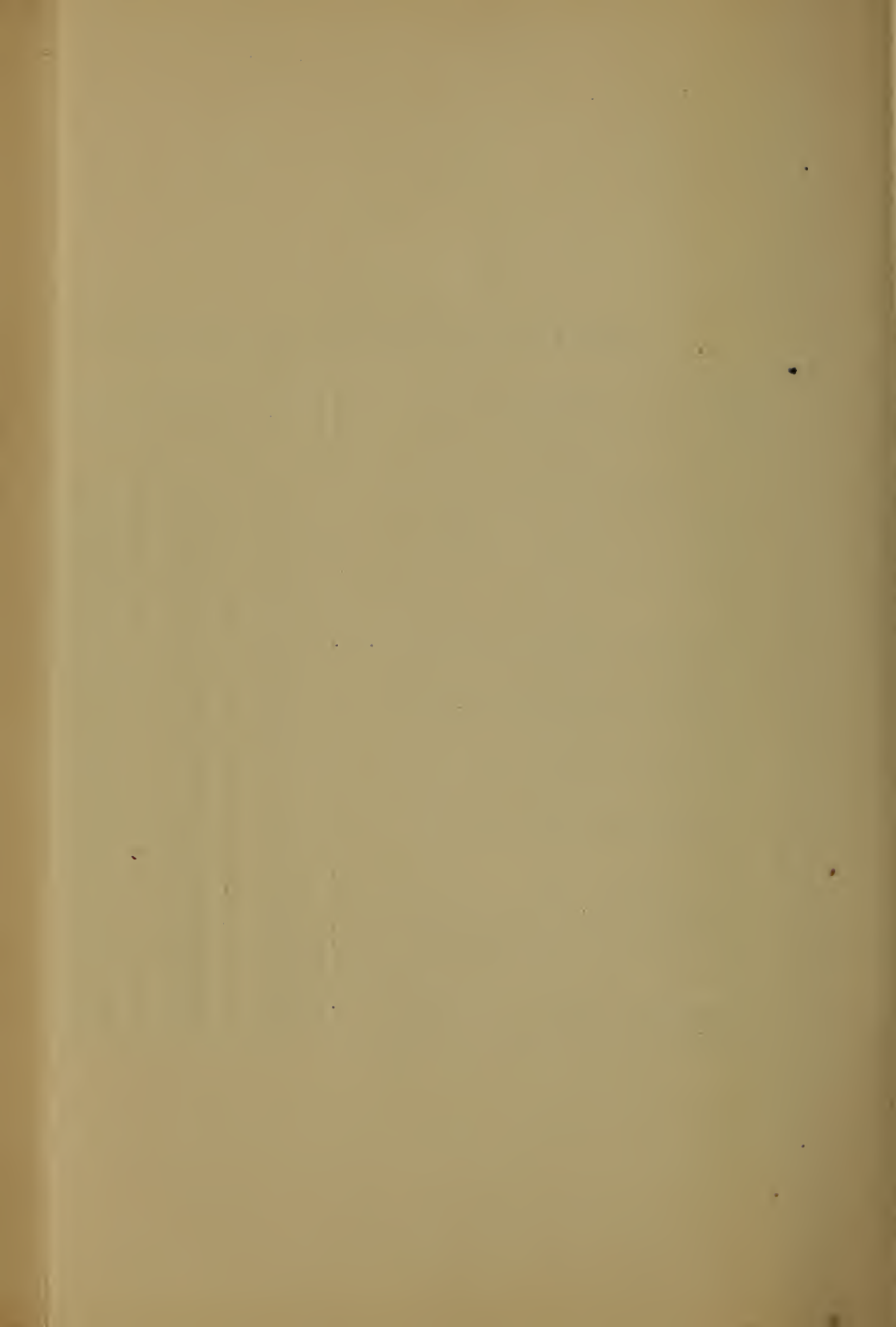
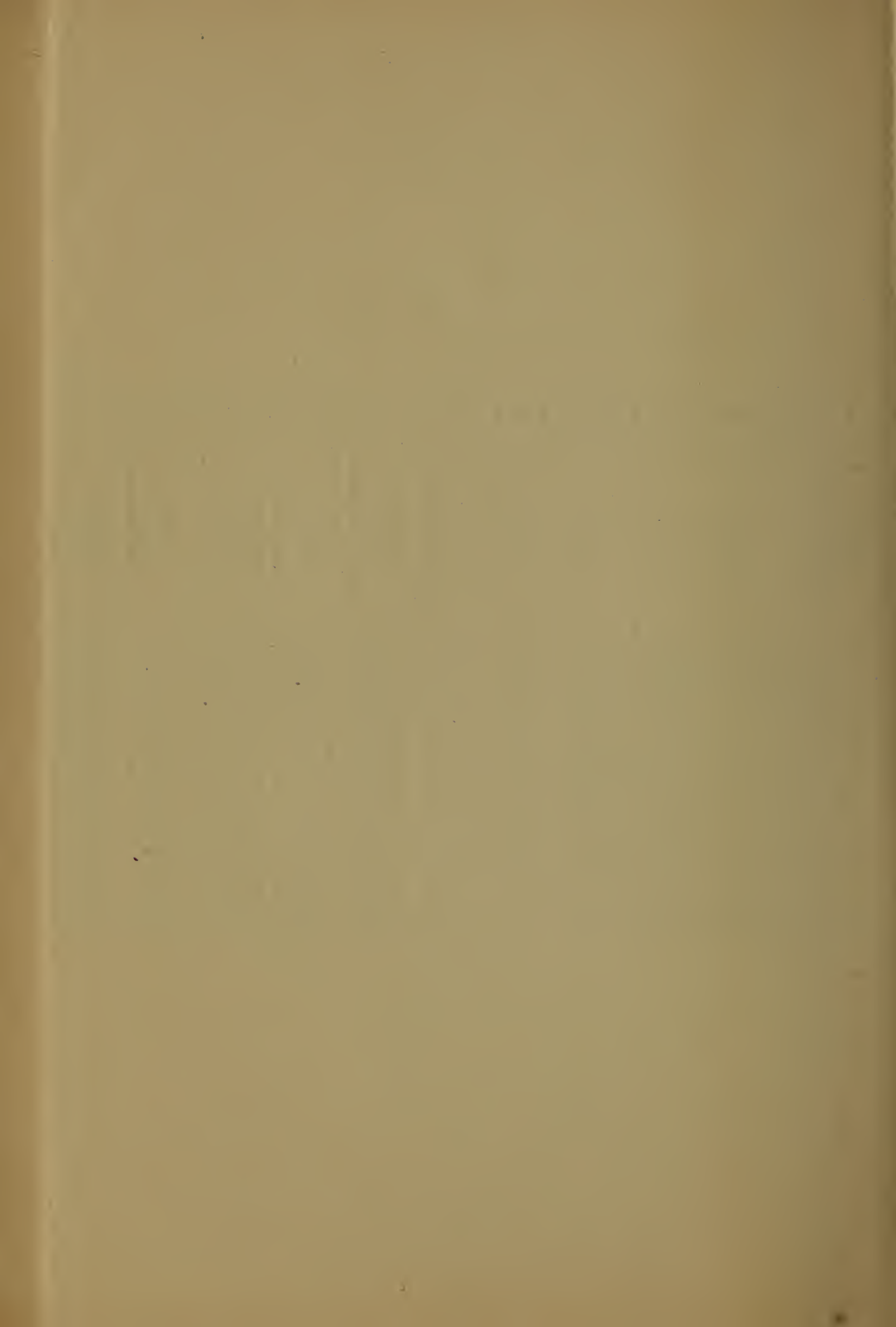


TABLE II.
ULTIMATE ANALYSES OF COALS CLASSIFIED IN THE ORDER OF THEIR RESPECTIVE CALCULATED CALORIFIC POWERS.

Analysis Number.	NAME OF COAL AND LOCALITY.	Moisture.	Volatile Matter.	Fixed Carbon.	Asb.	Sulphur.	Total Carbon.	Total Hydrogen.	Oxygen.	Nitrogen (* assumed).	Carbon in Hydrocarbon.	Hydrogen in Hydrocarbon.	Hydrogen in Combined Water.	Combined Water.	Calculated Calorific Power B. H. U.	Calculated Calorific Intensity, degrees F.	Theoretical Evaporation from and at 212° F. Lbs. Water.
11	Big Muddy, Jackson Co., Ill.....	6.35	31.50	55.25	6.90	2.02	69.80	5.26	8.35	1.33	14.55	4.216	1.044	9.934	12,567	3,942	13.0
12	Ellsworth, Macoupin Co., Ill.....	9.26	42.22	42.17	6.35	2.62	67.08	5.22	7.97	*1.5	24.91	4.225	0.996	8.966	12,175	4,727	12.6
13	Mt. Olive, Macoupin Co., Ill.....	10.38	36.68	46.10	6.84	3.53	64.68	5.70	7.37	*1.5	18.58	4.78	0.92	8.29	11,763	4,517	12.2
14	Reinecke, St. Clair Co., Ill....	7.56	39.81	42.49	10.14	4.02	64.86	5.13	6.79	*1.5	22.37	4.28	0.85	7.64	11,720	4,662	12.1
15	Johnson's, St. Clair Co., Ill....	5.50	40.14	40.53	13.83	4.80	64.06	5.02	5.298	*1.5	23.53	4.298	0.662	5.96	11,723	4,722	12.1
16	Loose's, Sangamon Co., Ill.....	10.71	37.62	45.07	6.60	2.39	65.22	4.90	8.68	*1.5	20.15	3.85	1.05	9.73	11,479	4,621	11.9
17	Riverton, Sangamon Co., Ill.....	11.06	77.94	42.98	8.02	3.27	64.10	4.86	7.19	*1.5	21.12	3.90	0.90	8.09	11,406	4,635	11.8
1	Pittsburgh, Pa., Coking Coal....	1.43	30.22	61.87	6.48	1.35	79.81	5.98	4.80	*1.5	17.94	5.38	0.60	5.40	14,415	4,735	14.9
2	Glen Mary, Scott Co., Tenn.....	2.15	31.47	61.63	4.75	0.94	76.68	6.09	4.89	*1.5	18.05	5.48	0.61	5.50	14,422	4,731	14.9
3	Spadra, Johnson Co., Ark.....	1.47	13.27	78.63	6.63	1.60	83.74	4.52	0.54	*1.5	5.11	4.453	0.067	0.607	14,420	4,797	14.9
4	Indiana Block.....	3.50	32.50	63.00	1.00	0.98	82.70	4.77	8.81	1.74	19.70	3.669	1.101	9.911	14,020	4,839	14.5
5	Jenny Lind, Sebastian Co., Ark.....	1.26	17.64	72.48	8.62	2.11	78.48	4.96	3.18	*1.5	6.00	4.56	0.40	3.58	13,964	4,847	14.4
6	Pittsburgh Coal (average of 5 boiler tests).	1.80	35.34	54.94	7.92	1.97	75.66	5.69	5.46	*1.5	20.72	5.01	0.68	6.14	13,684	4,705	14.2
7	Huntington, Ark.....	1.30	18.90	73.15	6.65	0.75	79.65	5.58	4.66	*1.5	6.50	4.998	0.582	5.242	13,752	4,651	14.2
8	Briar Hill, Mahoning Co., Ohio.....	2.47	31.83	64.25	1.45	0.56	78.99	5.92	11.50	1.58	14.74	4.48	1.44	12.94	13,714	4,223	14.2
9	Coal Hill, Johnson Co., Ark.....	1.35	14.93	74.06	9.66	3.04	77.52	4.52	2.48	*1.5	3.46	4.24	0.31	2.79	13,713	4,865	14.1
10	Hocking Valley, Ohio.....	8.25	35.88	53.15	2.72	0.43	72.29	6.53	8.28	*1.5	19.14	5.50	1.03	9.31	13,414	4,617	13.9



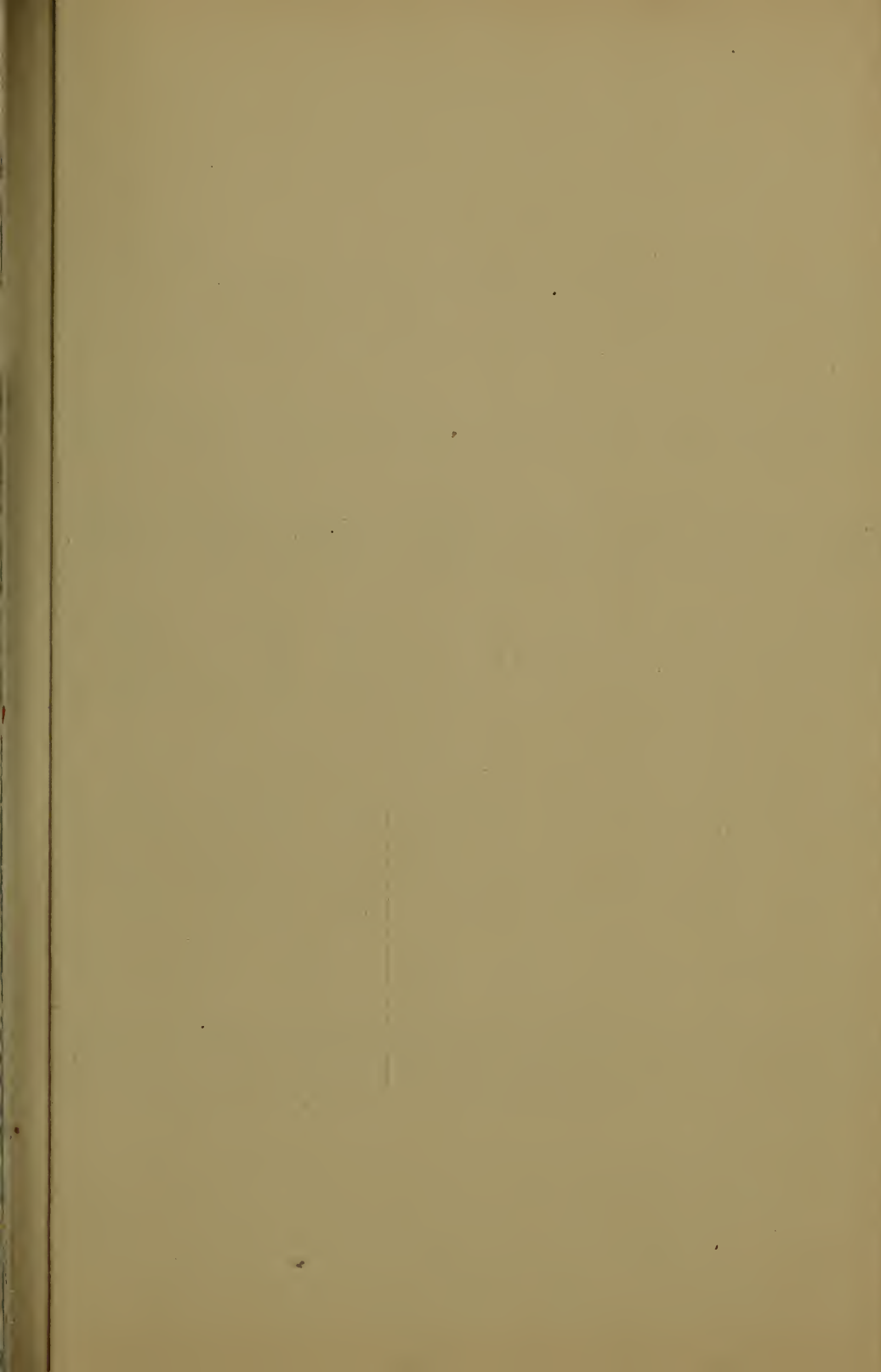


TABLE III.

RESULTS OF BOILER TESTS ARRANGED IN THE ORDER OF THEIR RESPECTIVE EVAPORATIVE POWERS.

Serial Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Test made by.....																																					
Kind of Boiler.....	Tubular.	Tubular.	Tubular.	Horizontal Return Tube.	Return Tubular.	Horizontal Cylindrical Flue, two Boilers.		Tubular Battery.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Tubular.	Return tubular.	Tubular.	2 Tubular each.	Heine safety boiler.	Tubular battery.	Firmenich boiler.	Heine safety boiler.	4 Heine safety boil- ers each.	Return tubular.	Tubular.	Tubular.	Return tubular.	Return tubular.	Return tubular.	
Principal Dimensions of parts of Boiler.....	26' x 4' 8-9" tubes.	4' diam. 22' long. 12-6" tubes.	4' diam. 22' long. 12-6" tubes.	Shell 48" diam. 20' long. Steam Drum 32" x 7' Mud Drum 18" x 5'	54" diam. Shell 16' long. 36-4" tubes.	Shell 60" x 17'8" Flues 18-6" x 18' Drums 36" x 9' Mud drums 14" x 6'		Two Shells 48" x 20' 24 Tubes 6" x 20'	5' diam. 16' long. 36-4" tubes.	5' diam. 16' long. 36-4" tubes.	5' diam. 16' long. 36-4" tubes.	16' x 5' 16-4" tubes.	16' x 5' 16-4" tubes.	16' x 5' 16-4" tubes.	5' diam. 16' long. 36-4" tubes.	5' diam. 16' long. 36-4" tubes.	16' x 5' 16-4" tubes.	16' x 5' 16-4" tubes.	16' x 5' 16-4" tubes.	16' x 5' 16-4" tubes.	16' x 5' 16-4" tubes.	16' x 5' 16-4" tubes.	54" diam. 16' long. 36-4" tubes.	4' x 16' 32-4" tubes.	5' diam. 22' long. 30-6" tubes.	1 shell 48"x18'6" 85 tubes 3½"x16'	2 shells 60"x22' 40 tubes 6"x22'	7 shells 30" x 20' 324 tubes 3" x 16'	1 shell 48" x 18' 6" 85 tubes 3½" x 16'	2 shells 30" x 18' 6" 113 tubes 3½" x 16'	54" diam. 16 ft. long. 36-4" tubes.	20' x 4' 12-6" tubes.	20' x 4' 12-6" tubes.	54" diam. 16' long. 36-4" tubes.	54" diam. 16' long. 36-4" tubes.	54" diam. 16' long. 36-4" tubes.	
Square feet of Heating Surface.....	705	1199	1199	520	730	1394	1394	1090	750	750	750	750	750	750	750	750	750	750	750	750	750	750	730	670	1860	1287	1860	4725	1287	6752	730	1090	1090	730	730	730	
Square feet of Grate Area.....	22.5	42.5	42.5		22.5	48	48	38.25	24	24	24	25	25	25	24	24	28	28	28	28	24	24	22.5	20	41	35	41	72	35	192	22.5	51.23	38.66	22.5	22.5	22.5	
Ratio of Grate Area to Heating Sur- face.....	1:31	1:28.2	1:28.2		1:32.4	1:29	1:29	1:28.5	1:31	1:31	1:31	1:30	1:30	1:30	1:31	1:13.25	1:23.21	1:23.21	1:23.21	1:31	1:31	1:31	1:31	1:32.4	1:33.5	1:45.3	1:36.77	1:45.36	1:65.62	1:36.77	1:35.16	1:32.4	1:21.27	1:28	1:32.4	1:32.4	1:32.4
Duration of Trial—Hours.....	9	5	5	12.17	11.75	10	10	9	11	11	11	7	7	7.5	82.5	8	8	9	7	8	11.5	10	11	7.5	5	10	10	5	6	5	344.3	7.42	10	10	6.6	6.5	8.16
Mean absolute Steam Pressure in Pounds.....	78.5	90	87		89	113	113	81	49.25	57.74	51.33	66	73.5	65	52.1	45	43	66.8	40.7		58.05	57.66	51.33	84.8	80	92.4	92.4	98	94	97	105.6	91	71.4	70.64	83.4	90	91
Average temperature of Feed Water Degs. F.....	197.3	81	81	197	97	207	207	180	158.1	168.85	159.6	149	159.4	138.2	164.6	186	173	164	171		152.6	160.6	159.4	64.8	190	214	106.1	202	204	202	199.4	63.6	151.4	166.74	171	62	62
Pounds of coal burned per hour, or- dinary damp state.....	550	780	983	457.6	359.7	1178.9	1210.1	532	673	640	550	437.42	419.71	520	686.06	750	463.9	476.66	571.4	600	678	720	673	228.4	300	990	870	1290	1804	1200	3576	182.9	1112.4	1260	230.2	218.9	219.5
Percent of ashes or waste in coal..	14.8	23	8	17.75	15.4	12.7	11	17.5	12.86	12	14.04	13	13	14.2	12.57	10.5	13.16	12.1	13.67	13	13.1	13.7	11.9		16.69	11.6	6.4	11.6	12	15.5	16.05	20	5.38	6.86	10.3	10.6	8.2
Pounds of coal burned per square foot of Grate Area per hour.....	24.4	18.35	23.13		16	24.6	25.2	13.91	28	26.66	22.9	17.5	16.8	20.9	28.53	31.25	16.56	17	20.4	25	28.25	30	28	10.15	15	24.15	24.8	30.7	25.05	34.3	18.63	10.16	21.76	32.59	13.15	13.28	16.26
Pounds of water apparently evaporat- ed per hour.....	2905	3320	5217.15	2419	1831.7	6360	7110	2813	3717	3645	3330	2064	2163.42	2666.66	3939.03	4480	2771.7	2872	3567	3672	3594	4172	4120	1246	1911.6	5765.4	5829.2	8171	11701	8663	26130	1220.3	7773	9185.1	1782	1481	1552.2
Pounds of water evaporated per hour per square foot of Heating Surface from and at 212° F.....	4.33	3.27	5.13	4.9	2.9	4.69	5.1	2.76	5.34	5.22	4.8	3.02	3.16	3.90	5.70	6.35	3.93	4.13	5.17	5.34	5.22	6.02	5.94	1.98	3.01	3.21	5.19	4.60	2.59	7.05	4.08	1.93	7.81	9.1	2.58	2.34	2.42
Pounds of water evaporated per pound of coal from and at 212° F.	5.54	5.02	6.25	5.57	5.84	5.54	6.07	5.65	5.95	6.14	6.00	5.17	5.57	5.68	6.18	6.35	6.36	6.55	6.83	7.29	5.78	6.28	6.62	6.32	6.64	6.02	7.68	6.80	6.88	7.57	7.69	7.72	7.66	7.87	8.18	7.79	8.6
Kind of Coal used	Dorsey Nut Madison Co., Ill.	Mt. Olive Slack, Macoupin Co., Ill.	Mt. Olive, Macoupin Co., Ill.	Vulcan Nut St. Clair, Ill.	Vulcan Nut St. Clair, Ill.	St. Clair, Ill.	St. Clair, Ill.	Staunton slack and nut, Ma- coupin Co., Ill.	Staunton, Macoupin Co., Ill.	Staunton, Macoupin Co., Ill.	Confidence Madison Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Collins- ville, Madi- son Co., Ill.	Troy, Madison Co., Ill.	Troy, Madison Co., Ill.	Troy, Madison Co., Ill.	Coal Hill, Johnson Co., Ark.	Ellsworth, McLean Co., Ill.	Bryden, William- son Co., Ill.	Bryden, William- son Co., Ill.	Freeburg, St. Clair Co., Ill.	Freeburg, St. Clair Co., Ill.	Freeburg, St. Clair Co., Ill.	Freeburg, St. Clair Co., Ill.	Jenny Lind Sebastian Co., Ark.	Big Muddy, Jackson Co., Ill.	Big Muddy, Jackson Co., Ill.	Hunting- ton, Ark.	Pitts- burgh, Pa.	Pittsburgh Coking Coal.



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